Universities as Conservation Sites for Woodpecker Species in the Southeastern US

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Introduction

There are many threats that contribute to the decline of bird populations including climate change, deforestation, urbanization, invasive species, habitat loss and fragmentation, hunting, and pollution (Loss et al. 2012; Sih et al. 2011). Rosenburg (2019) stated that a wide-spread loss of over a billion breeding individuals has occurred in the last half-century and the loss occurred across a wide range of species and habitats. Long term surveys that record the fluctuation of bird species numbers indicated that the net loss in total abundance is 2.9 billion birds across almost all biomes (Rosenburg et al. 2019). Other long-term surveys have shown 303 out of 529 bird species have experienced a population decline (Rosenburg et al. 2019). Birds that live in forest biomes experienced a larger loss with a cumulative reduction of more than 1 billion birds (Rosenburg et al. 2019). Birds are important to the ecosystem due to the roles they have within it. By using birds as indicator species, we can understand the health of the ecosystem (Northrup et al. 2019).

Impact of Human Activity

The human activities that have the most influence on global bird biodiversity are climate change and land-use change (Northrup et al. 2019). Northrup et al. (2019) stated that we need more studies on how climate change and land-use change work synergistically to impact bird biodiversity. The global decline of bird biodiversity has been due to land-use change and is one of the most frequent and direct threats to bird biodiversity (Tilman et al. 2017). Around 80% of all threatened terrestrial bird and mammal species are at risk due to transforming their habitats into agricultural landscapes (Tilman et al. 2017). In recent decades, the importance of managing and protecting our forests has become a global issue due to the high rates of deforestation and degradation (Newton et al. 2009). Human activities such as logging, livestock husbandry, crop cultivation, urbanization, and slash-and-burn farming, have contributed to forest biodiversity loss despite conservation efforts (Newton et al. 2009). Other practices such as harvesting trees for their timber were higher in smaller fragments of forest. As humans continued to use these smaller forest fragments, the forest became more accessible for humans to exploit and let their livestock use these areas, which in turn caused more degradation and fragmentation of the forest (Newton et al. 2009). Habitat loss is one of the biggest factors to the recent decline of many bird populations (Negret et al. 2021).

Urbanization and Bird Populations

The growth of the human population has also had profound effects on avian diversity as urbanization changed natural habitats (Gagne et al. 2016). As human populations grew and urbanization increased, breeding bird species richness and abundance declined (Gagne et al. 2016). Autoregressive modeling and multi-model inference to the North American Breeding Bird Survey and US Census data from 48 urban areas showed that human population size was an important predictor of breeding bird species richness (Gagne et al. 2016). The results of the experiment showed a negative correlation: as human populations grew and urbanization increased, breeding bird species richness and abundance declined (Gagne et al. 2016). Gagne et al. (2016) suggested the reasons for this negative correlation were poor land management, pollution, habitat loss, and fragmentation of forested areas, making it more challenging for bird species to sustain a breeding population. Therefore, conservation strategies should be implemented within urban areas so that birds and humans can coexist and thrive together. Similarity to Newton et al. (2009) in more rural areas conservation strategies including reserving important habitats, restoring fragmented habitats, educating people about the interactions of the surrounding wildlife and humans, replacing paved areas, and built land in urban environments with complex landscaping elements such as native plants, grasses, and trees should be implemented (Marzluff and Rodewald 2008).

Biodiversity

What has been done to improve bird biodiversity?

Canedoli et al. (2018) analyzed different environmental features within an urban park and a peri-urban forest environment. Peri-urban forests are defined as areas located immediately adjacent to an urban area (Canedoli et al. 2018). They took walking surveys in 15 sites that fit this classification and listed all of the environmental factors within the sites that had an influence on the avian biodiversity within the site (Canedoli et al. 2018). The results showed that areas with a mixture of woodland covers and with bodies of water showed greater species presence and abundance than parks that did not have any bodies of water within them (Canedoli et al. 2018). The importance of clean water accessibility in urban areas to bird populations cannot be overstated it allows access to drinking water, preening, and bathing. This is just one important consideration when designing urban areas that support bird biodiversity.

Conservation of Bird Species

Strategies

Countermeasures must be taken to conserve avian species. We must understand what factors are affecting certain species of birds and what changes need to be made to support abundance and richness. One strategy is to develop green spaces in urban areas (Canedoli et al. 2018; Callaghan et al. 2019). Callaghan defines green spaces as areas that are filled with vegetation such as grasses and trees and are used for recreational and aesthetic purposes. Using the citizen science data in eBird Callaghan et al. (2019), analyzed around 4 million complete checklists. eBird defines a complete checklist in which the citizen scientist included all birds seen/heard on the reported list, Callaghan focused on a subset of checklists that met the following criteria, recordings lasted from 5 to 240 minutes, and they followed 'traveling' or 'exhaustive' protocol, and citizen scientists traveled at least 2.5km (Callaghan et al. 2019). The results showed greater species richness and diversity within urban green spaces compared to the natural green spaces, potentially due to the habitat heterogeneity observed in the urban green spaces. Habitat heterogeneity is the diversity of habitat types which can provide suitable habitat requirements for a variety of species of birds (Callaghan et al. 2019).

Bioindicators

What is a bioindicator?

Bioindicators are species or a group of species whose niche reflects the abiotic or biotic state of an ecosystem, environment, or biodiversity of a habitat (Addisu and Girma 2019) Bioindicators are used to predict trends in an ecosystem and to determine its health (Addisu and Girma 2019). The use of bioindicators to monitor the state of an ecosystem is due to the high complexity and diversity within an ecosystem making it difficult to monitor all the taxa within the ecosystem (Addis and Girma 2019). The use of bioindicators in conservation practices as a tool that is simple and cost effective and allows for effective monitoring of ecological processes while both evaluating current trends and predicting future trends (Addis and Girma 2019).

Examples of birds as bioindicators

The use of birds as bioindicator species is common practice. Birds are detectable and can be observed more easily than many other vertebrate species in the environment, due to their abundance and vocal displays (Addis and Girma 2019). Researchers have studied how a particular species of bird like the woodpecker can indicate bird biodiversity within a habitat (Morelli et al. 2017) and used their findings to advocate for protected areas for species that are losing habitat due to human activity (Hickcox et al. 2019). Morelli et al. (2017) studied Eurasian Cuckoo birds because they are brood parasites and rely on other species of birds such as Sparrows, Ravens, Magpies to rear their young the presence of Cuckoos can be used as a bioindicator of bird hotspots; areas of high bird species richness and diversity (Morelli et al. 2017). Morelli et al. (2019) hypothesized that the Common Cuckoo (*Cuculus canorus*) was an effective surrogate for bird taxonomic diversity. They tested this hypothesis by comparing the predictive power in ten different countries within Europe and two countries in Asia. A total of 65,234 observations of birds in 3,592 sample areas showed that richness ranged from 12 species (Finland) to 28 species (San Marino and Switzerland) in Europe, while it ranged from 10 to 17 species in Asian (Morelli et al. 2017). A higher species richness value occurred in sample sites in which the Common Cuckoo was observed (Morelli et al. 2017).

Hickcox et al. (2019) studied the effectiveness of protected areas on the distribution of penguin species around the world. These geographical areas are managed with the goal of conserving biodiversity, ecosystem services, and cultural values (Hickcox et al. 2019). Penguins have been affected by climate change, habitat loss and degradation, oil spills, commercial fishing, and pollution. There are 18 known species of penguins and 10 of those species are vulnerable or endangered (Hickcox et al. 2019). Penguins are important bioindicators because they occupy terrestrial and marine habitats and can indicate how other marine life is impacted

(Hickcox et al. 2019). Hickcox studied the breeding ranges of penguin species and their range overlaps. Penguins spend most of their time in the water but can only breed on land at specific times of the year, and they return to the same nesting areas every year (Hickcox et al. 2019). Hickcox recommended that these protected areas include nesting sites for penguins in order to increase reproductivity. By compiling a global-scale dataset of the terrestrial geographic distribution of the 18 penguin species (family Spheniscidae) and using spatial data of known protected areas, they discovered that all the penguin species were protected to some degree by at least one protected area (Hickcox et al. 2019). This analysis also discovered seven hotspots of penguin biodiversity where 4 to 5 penguin species reproduce (Hickcox et al. 2019). Such research as Hickcox, et al. (2019) and Morelli et al. (2017) indicates the importance of providing conservation areas for birds.

How have bioindicators been used in conservation work?

Padoa-Schioppa et al. (2006) stated that bioindicators must have the following qualities high data synthesis value, user benefit, and relevancy for both political choices and management purposes. These are important when making conservation plans and identifying areas that need government protection. The practice of using bioindicators in ecology to test specific circumstances and measure degradation and restoration processes in different environments (Padoa-Schioppa et al. 2006). Different bioindicator concepts such as flag, umbrella, keystone, and focal species have been defined within the disciplines of conservation biology and landscape ecology (Padoa-Schioppa et al. 2006). Padoa-Schioppa defines a focal species concept as a species or group of species that have spatial and functional requirements that effectively define environmental limits for the preservation of other species in that environment. Different studies have used birds as a focal species in conservation plans for faunal species at different spatial gradients from continental to regional (Padoa-Schioppa et al. 2006).

Woodpeckers

Why are Woodpeckers Bioindicators?

There are over 210 species of woodpeckers, and these species play an important role in bird communities around the world (Virkkala 2006). Woodpeckers provide cavities for secondary cavity-nesters such as Eastern Bluebirds (*Sialia sialis*), European Starling (*Sturnus vulgarnis*), and Carolina Wren (*Thryothorus ludovicianus*; Virkkala 2006; Drever et al. 2008; Drever and Martin, 2010). Woodpeckers are also sensitive to habitat change since they are reliant on dead wood for foraging and building cavities (Virkkala 2006). Many woodpeckers live in forested areas that fulfill these specific needs. Therefore, woodpeckers can be used as indicators of forest biodiversity and bird diversity (Virkkala 2006; Drever et al. 2008; Drever & Martin 2010). Many woodpecker species are non-migratory and will reside in the same habitat year-round, this attribute can help us understand their habitat over the course of the year and observe any fluctuation in the habitat health (Virkkala 2006). The presence of woodpeckers can therefore be used to measure and evaluate the efficacy of forest restoration projects (Virkkala 2006).

How do woodpeckers indicate biodiversity?

Woodpecker foraging and nesting strategies can positively impact the forest bird richness and abundance (Drever et al. 2008; Drever and Martin 2010). A nest web is the interdependent relationship between primary cavity nesters, secondary cavity nesters, and weak cavity excavators which all utilize nest-cavity resources (Martin and Eadie, 1999). Woodpeckers are primary cavity nesters in the nest web (Kilgo and Vukovitch 2014) and other bird species in the nest web use the cavities they build once they are abandoned (Virkkala 2006; Drever et al. 2008; Drever and Martin, 2010). Woodpeckers' reliance and utilization of dead trees and snags also attracts other bird species to forested habitats. The foraging of these snags and dead trees exposes the underlying tree material which other bird species are attracted to and may inhabit (Drever et al. 2008).

Mikusiński (2001) studied the correlation of woodpecker species and biodiversity of forest bird species by observing 10x10km plots with at least 70 observed species. 2317 plots in Poland were studied and woodpecker species richness and forest bird species richness were compared (Mikusiński et al. 2001). The results showed that the presence or absence of certain species of woodpeckers within a plot correlated to higher levels of species richness then plots that did not have a diverse or high level of woodpecker species richness (Mikusiński et al. 2001). The diversity of woodpecker species within a habitat has shown the presence of a higher diversity of birds and the destruction of these habitats has caused an overall decrease in avian biodiversity (Radford et al. 2005; Virkkala 2006; Drever et al. 2006).

Woodpeckers and Habitat Loss

Human infrastructure such as buildings, automobiles, communication towers, wind turbines, and aircraft have killed many birds (Loss et al. 2012). Sih (2012) stated that habitat loss is likely the most important factor that has caused bird species decline and extinction. As humans continue to build to satisfy our needs, other species find it more difficult to survive. Habitat loss negatively impacts the species richness of birds including woodpeckers within woodland habitats (Radford et al. 2005; Ilsoe et al. 2017; Vergara-Tabares et al. 2018). Vergara-Tabares et al. (2018) studied global trends of woodpecker species and how they are influenced by habitat loss on different continents and the results showed that anthropized areas overlapped with high woodpecker species richness areas that averaged between 15-23 species. The study indicated the need for more protected areas for woodpeckers. They found that the most diverse woodpecker hotspots are in Southeast Asia and in the eastern Andes of South America, but the majority of these areas have been modified to suit human needs (Vegara-Tabares et al. 2018). Vegara-Tabares et al. (2018) concluded that there needs to be more protected areas and that the scientific community should take on the responsibility of better educating the public about the negative effects of habitat loss. This is important because the woodpecker hotspots are in areas with high deforestation rates and conservation actions should be taken in these areas (Vegara-Tabares et al. 2018).

Environmental Factors Affecting Woodpeckers

Due to the loss of tree coverage many forest dwelling bird species, including woodpeckers, have been negatively impacted. A disproportionate loss of species takes place when 10-30% of the habitat coverage is taken away from a landscape (Radford et al. 2005). Radford conducted bird surveys in 24 landscapes (each 100km^2) and measured habit coverage which ranged from 2% to 60%. Vergara-Tabares et al. (2018) conducted similar research but focused solely on woodpecker species while Radford focused on woodland-dependent bird species. By conducting these bird surveys both Radford et al. and Vergara-Tabares et al. were able to measure the species richness of different forested landscapes that were in close proximities with urbanized areas across the globe in areas such as Southeastern Asia, eastern Andes, and western Africa. They found that woodland dependent bird species richness and tree coverage had a positive relationship. Areas that had less than 10% tree coverage showed a significant drop in the number of species in that landscape (Radford et al. 2005).

The Radford et al. (2005) study is important for understanding the significance of tree coverage for a variety of woodland bird species. Woodpeckers would be one of these woodland bird species that would be affected by changes to tree coverage, species richness of woodpeckers is dependent on tree coverage (Ilsoe et al. 2017). The tree availability in the past had a positive effect on woodpecker species richness in global hot spots for woodpecker species (Ilsoe et al. 2017). This supports Radford's and Vergara-Tabares conclusions on how tree coverage influences bird diversity, but it focuses on woodpecker species and how they are affected by different rates of deforestation around the world.

Woodpeckers and Conservation Management

The most important aspect to woodpecker conservation management is to protect the dead trees and snags within the habitat. Pasinelli (2007) stated that the removal of dead trees and snags is one of the most detrimental aspects of intensive forestry in the temperate zone. The lack of dead trees and snags forces woodpeckers to build their nests in living trees and even though there are still suitable nesting sites, it significantly reduces their options (Pasinelli 2007). Due to this sensitivity to environmental change, it is important to understand the ecology and niches of specific woodpecker species to properly formulate a conservation plan that will optimize their survival (Pasinelli 2007). Pasinelli (2007) observed nest selection of two species of woodpeckers in Northeastern Switzerland, the Middle-Spotted Woodpecker (*Leiopicus medius*) and the Great Spotted Woodpecker (*Dendrocopos major*) over a 6-year period. The study area was 800ha of forested area and consisted mainly of oak (Q*uercus sp.*) and hornbeam (*Carpinus sp.*) trees Nest cavities of both woodpecker species were found in oak trees. This study showed that woodpeckers show a preference to large trees and dead trees (Pasinelli 2007). Additional studies need to be conducted on how woodpeckers nesting habits relate tree type and availability.

To further study the importance of snags in a habitat, Kilgo and Vukovich (2014) studied the impact of snag creation in a snag pulse experiment on a population of Red-Headed Woodpeckers (*Melanerpes erythrocephalus*). This experiment was conducted for eight years and three treatments were used which included snag removal, an unmanipulated control, and a snag pulse, snag pulse is the creation of snags (Kilgo and Vukovich 2014). During the first two years following treatment, the abundance of Red-Headed Woodpeckers did not differ between the three treatments, but after another two years of observation the abundance of Red-Headed Woodpeckers within the snag pulse treatment area surpassed the control and removed snag treatment sites (Kilgo and Vukovich 2014). The peak population of woodpeckers in the snag pulse treated areas was six times higher than the controlled site. These findings confirm the importance of snags to nesting woodpeckers in addition to cavities in trees. Woodpecker conservation efforts should focus on of snags in the forested habitat (Kilgo and Vukovich 2014).

Summary

Woodpeckers provide an indication of biodiversity and overall forest health. They are important bioindicators because they are sensitive to changes in the environment. The destruction of forest habitats, removal of snags, and habitat fragmentation has made it more challenging for them to survive and thrive. Understanding the impacts of human activity on woodpeckers and other birds can influence politicians, government officials, and citizens to protect and even create additional habitats for them. University campuses are one habitat to consider as a part of conservation in addition to parks and nature areas.

Urbanization has altered many habitats and has disrupted the landscapes' ability to perform ecological processes that many avian species depend on (Audubon.org 2021). Humans have dominated these landscapes and made them unsuitable for birds to live in. We must take responsibility to repair the damages to bird habitats (Audubon.org 2021). Creating bird-friendly communities and habitats in urban, suburban, and rural areas will help recreate and reestablish suitable ecosystems that birds and humans will be able to thrive in (Audubon.org 2021). Adding more native plants, providing birdhouses, roosting towers, nest platforms, and creating fewer buildings that are hazardous to birds can only be accomplished if humans understand these structures impact avian health, and how birds interact with environments dominated by humans (Audubon.org 2021). I aim to understand human impacts on the local bird community, and how human health may benefit from improving the health of bird populations.

Research Questions

Does of presence or absence of woodpeckers predict biodiversity in other bird species on University campus?

Does developed land or undeveloped land impact the presence or absence of woodpeckers and other bird species on a University campus?

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Title: Woodpeckers as Bioindicators of Avian Biodiversity on a University Campus

Abstract: Anthropogenic change leads to habitat fragmentation and habitat loss impacting forest birds. Woodpeckers are good bioindicators of healthy forest ecosystems. They require forested habitat that has plenty of shelter, roosting and nesting sites, snags, vegetation, and insects. Examining woodpecker habitats and behavior in close proximity to human activity can inform preservation efforts. We aimed to evaluate the University of North Carolina at Pembroke (UNCP) campus, located in the southeastern part of the US, for woodpecker diversity and abundance along an urban agricultural gradient. We split the campus into two study sites of 17ha each and conducted weekly walking surveys during which we mapped woodpecker locations and behaviors. Forested areas within the north site totaled 11ha (64.7%) while forested area in the south site total 1.6ha (8.9%). The data showed that UNCP supports a diverse assemblage of woodpecker species establishing their own territories. We found 6 species on campus during our surveys. Three of these, *Melanerpes carolinus* (Red-bellied Woodpeckers), *Dryobates pubescens* (Downy Woodpeckers), and *Colaptes auratus* (Northern Flickers), established territories on and around the campus during the study. Comparing the tree basal area between the two sites we found that tree species composition was similar between the two sites. To measure weather both sites supported similar biodiversity of avian species, we counted species richness and calculated the Shannon Index to determine species evenness, and found that the north site had an H of 2.55 in the fall and an H of 3.25 in the spring. The south site had a H of 2.28 in the fall and an H of 2.34 in the spring. The north site average species richness per month was 37.17 whereas the south site average species richness per month was 25.33. We found that the woodpecker species richness and date were significant factors in determining avian biodiversity $R^2 = [0.529]$ $p< 0.05$. Our data illustrates how important it is for universities to be aware of and carefully plan their green spaces by providing forested habitat patches suitable for woodpeckers and other birds. Woodpeckers can then be used as indicator species of forest health on campus.

Keywords: woodpeckers, agriculture, University campus, biodiversity, birds

Introduction

Woodpeckers (family Picidae) are essential to the forested environments. One way they help the environment is by controlling the wood borer pest populations by consuming them (Virkkala 2006). Woodpeckers also generate access to sap as a food resource to other animals such as mice, squirrels, beetles, butterflies, moths, hummingbirds, and other bird species (Mansuco,2014). Woodpeckers also build cavities and forage snags these actions also impact other bird species (Cockle 2011). Secondary cavity nesting species are incapable of creating their own cavities, so they are dependent on naturally occurring tree cavities or cavities that were created by primary cavity nesting species such as the six woodpecker species that we detected on campus (Virkkala 2006; Drever et al. 2008; Drever and Martin 2010; Cockle 2011; Kilgo and Vukovitch 2014). Populations of secondary cavity nesters can be limited in forested environments that lack in available cavities that they will use for nesting and roosting (Cockle 2011). Woodpeckers are essential because they create these cavities and are a priority for the conservation of cavity using communities as they have a direct impact on the abundance and diversity of cavity nesting species that cannot excavate their own cavities (Cockle 2011). Woodpeckers not only aid in the biodiversity and species abundance within a habitat but can also indicate the health of their forest habitat (Vikkala 2006).

Deforestation has impacted the tree coverage that many species rely upon for protection, breeding, nesting, and survival (Radford et al. 2005; Vergara-Tabares 2018). Woodpeckers are especially sensitive to deforestation, removal of dead trees and snags in forest management can negatively affect woodpecker populations (Pasinelli 2007). The loss of woodpecker species diversity within a forest environment can cause a loss of avian biodiversity in that environment (Drever et al. 2008). If woodpeckers did not provide cavity nesting sites for other bird species or remove bark from dying trees that exposes the substrate for other bird species to exploit, there would be a drop off on the avian biodiversity in that area (Drever and Martin 2010). Woodpeckers are bioindicators for avian biodiversity and forest health due to their sensitivity to the environment and the correlation of woodpecker species diversity with general avian species richness (Virkkala 2006; Drever et al 2008; Drever and Martin 2010).

Urbanization is one of the driving forces that has reduced biodiversity within forested habitats (Myczko et al. 2014). The effects of urbanization can negatively impact populations and due to the rapid alterations to their habitats, woodpeckers are susceptible to these environmental changes and cannot readily adapt to these changes (Myczko et al. 2014). Environmental factors within woodland patches such as percentage of deciduous species, openness of canopy, and shrub coverage does impact the woodpecker population and the loss of coverage does impact woodpecker species richness and abundance (Myczko et al. 2014). The Red-Headed Woodpecker (*Melanerpes erythrocephalus*) was once a very abundant species seen throughout southern Canada and southeastern United States, but their population numbers have decreased so drastically that they are now considered a threatened species (Frei et al. 2013). With the reduction of suitable habitats and the expansion of urban areas we may continue to see a decrease of Red-Headed Woodpeckers and overall woodpecker diversity as well (Myczko et al. 2014).

To understand the impacts of urbanization on avian biodiversity and forest health, woodpeckers are important to observe as they can indicate how well the ecosystem is adapting to the urbanization processes (Myczko et al. 2014). Myczko et al. (2014) wanted to understand how the local woodpecker population is utilizing the habitat and what type of areas they are establishing within their territories. If areas that are developed and humans reside in can support a diverse population of woodpeckers, then it is possible for it to support a diverse population of avian species (Virkkala 2006; Drever et al. 2008; Drever and Martin 2010).

To fully understand the habitat usage of woodpecker species it is important to know their migratory patterns and what areas they are inhabiting at different times during the year. The woodpecker species that inhabit Eastern North Carolina are Red-headed woodpeckers (*Melanerpes erythrocephalus*), Red-bellied woodpeckers (*Melanerpes carolinus)*, Downy woodpecker (*Picoides pubescens*), Red-cockaded woodpecker (*Leconotopicus borealis*), Hairy woodpecker (*Leuconotopicus villosus*), Pileated woodpecker (*Dryocopus pileatus*), Northern Flicker (*Colaptes auratus*) and a migratory species the Yellow-bellied Sapsucker (*Sphyrapicus varius*) (Merlin, 2020). The migratory patterns of the Red-headed woodpecker can be erratic because departure rates, directions, and distance traveled varying amongst individuals and populations (Vukovich and Kilgo 2013). The Northern Flicker population in North Carolina is mixed with both northern migrants and local residents (All About Birds 2020). While the Pileated, Red-bellied, Downy, and Hairy being are the non-migratory species in eastern North Carolina (All About Birds 2020).

My research explored the essential needs of woodpeckers, looking at how they can thrive while closely coexisting with humans and their use as bioindicators of total avian diversity. I analyzed how prevalent woodpeckers are in two different types of habitats. One habitat was a developed area, and the other was a forested edge habitat. Our first goal is to see how well the woodpecker species assemblage did as a bioindicator of the rest of the avian community. The second goal of this study is to understand what areas on University of North Carolina at Pembroke (UNCP) campus are used by which different species of woodpeckers. Analyzing the distribution of woodpeckers may reveal information on the health of the forested area around

UNCP, the biodiversity of birds on campus, and how active and abundant woodpeckers are in wooded edges and developed areas on campus. Ultimately my research will contribute to sustainability efforts on campus by understanding the potential for woodpecker conservation on the campus itself and in the natural-agricultural environment surrounding it.

Methods

Field Sight Description

To observe woodpeckers in forested and developed habitats I created two census areas on campus that are approximately 17ha each. The Northern census area is the forested area on campus (Figure 1). Located inside this plot is the campus garden which is surrounded by deciduous forest and has few buildings around it. Within this plot there are also two ponds that are surrounded by trees such as pines and oaks which woodpeckers prefer. Lastly, within the northern plot is a gravel parking lot that has a deciduous forest patch across from it. There is one building in this area, but it is not close to this forest patch.

The Southern census area is urbanized habitat; this census area contains majority of UNCP buildings (Figure 2). The landscapes within the plot are manicured so tree coverage is very low, and trees are spread apart. There is an artificial pond that within this manicured landscape. Around the chancellors' home is a strip of deciduous trees that provides more tree coverage. Lastly, there is a patch of deciduous forest used by the biology department for ecology lectures that is not manicured and provides tree coverage for the woodpeckers.

Territory Mapping:

I generated two census areas on campus one has a more urbanized environment while the other has a more agriculture environment. The developed area had 19 buildings in total, while the forested environment only had 9 buildings and also consists of trees and grass and parking lots. The developed area provided less area with tree coverage than the forested environment. A walking survey of each site was taken once a week per site from August 27th, 2020 – October 29th, 2020 and February 11th – April 15th, 2021 and a different route was taken each time to avoid bias (Bibby et al. 2000). Each study site was visited weekly, and whenever a woodpecker was heard or seen it was recorded on a map. Behaviors such as perching, singing, and calling were recorded at the exact location observed and recorded using standard territory mapping methods (Bibby et al. 2000). Once the data were collected, they were aggregated using ArcGIS (ESRI 2021).

Figure 1. Landscape composition of northern site. Showing buildings (blue), ponds (bright blue) paved areas (gray) trees (dark green), playing feeds and grassy areas (light green).

Figure 2. Landscape composition of southern site showing buildings (blue), paved areas (gray) trees (dark green), playing feeds and grassy areas (light green).

Tree Diversity

To understand how the bird species are utilizing the vegetation I analyzed the trees within the study area (Frohlich and Ciach 2020). I generated eight 10x10m plots within each study area. Within these plots I measured and identified all trees with a diameter at breast height (DBH) of at least 7cm (Frohlich and Ciach 2020). Snags and logs were also recorded in the survey. Recording DBH allows us to see how much space each tree within the area is taking up and observe the type of trees woodpeckers prefer to inhabit (Frohlich and Ciach, 2020). Snags and logs are also utilized by certain species of woodpeckers such as Northern Flickers, so they are recorded.

Avian Diversity

While recording woodpecker species encountered during the walking survey, all other bird species were recorded using the eBird app. Birds are recorded if they were seen or heard during the walking survey. To indicate if woodpeckers are a good indicator for bird biodiversity, I compared the species richness, abundance, evenness, and average count between the two study sites.

Statistical Analysis

I calculated the diameter at breast height (DBH) of each tree within each plot and found the total basal area of each species of tree. Using a two-way factor with replication ANOVA, I compared variation using basal area between the two sites. The species richness and species evenness were analyzed using eBird and Microsoft Excel (Microsoft® Excel® for Microsoft 365 MSO 16.0.13929.20222). To analyze weather woodpeckers are good bioindicators of total avian biodiversity on the UNCP campus I used a linear regression model, my predictors were date, woodpecker species richness, and percent forest coverage on each site. I used the Shannon index to analyze the species diversity, H is the Shannon index value below, Pi is the proportion of the individuals found in the *i*th species, ln as the natural logarithm, and s equals the number of species in the community (Cain et al. 2011).

$$\text{Shannon Index: } H = \sum_{i-1}^{\varsigma} p_i \, ln(p_i)$$

Results

Tree Basal Area and Species Composition on Campus

A total of nine tree species were found in at least one of the eight plots. The species found were, *Pinus taeda* (Loblolly Pine), *Pinus palustris* (Longleaf Pine), *Quercus nigra* (Water Oak), *Quercus laurifolis* (Laurel Oak), *Quercus phellos* (Willow Oak), *Liquidambar styracifua* (Sweetgum), *Nyssa sylvatica* (Black gum), *Acer rubrum* (Red Maple), *Acer palmatum* (Japanese Maple), *Prunus serotina* (Black Cherry), *Cornus florida* (Dogwood), *Betula nigra* (River Birch), and *Castanea mollissia* (Chinese Chestnut). The one snag that was recorded was a Black gum. The total basal area of each tree species within a manicured or wooded plot were used in the 2-Factor ANOVA with replication (Table 1). Tree species basal area was similar between measured plots (F= 1.39, df = 3, p = 0.2551).

Woodpecker Territories

I found that in the fall semester the Red-bellied Woodpeckers had four territories within the north site (Figure 3). Downy Woodpeckers had one territory in the north site (Figure 4). In the south site I documented one territory for Downy Woodpeckers (Figure 4), *Colaptes auratus* (Northern Flickers, Figure 6), and Red-Bellied Woodpeckers (Figure 3) during the fall season. In comparison the Red-bellied Woodpecker was the only species of woodpecker with documented territories in the spring semester (Figure 3). Due to the late arrival, April 22, 2021, of Red-headed Woodpeckers onto campus the territory determining criteria of two or more observations in a more than 10 days apart period were not met. They were observed in the same area only six days apart, so I suspect they were establishing breeding territories campus (Figure 5).

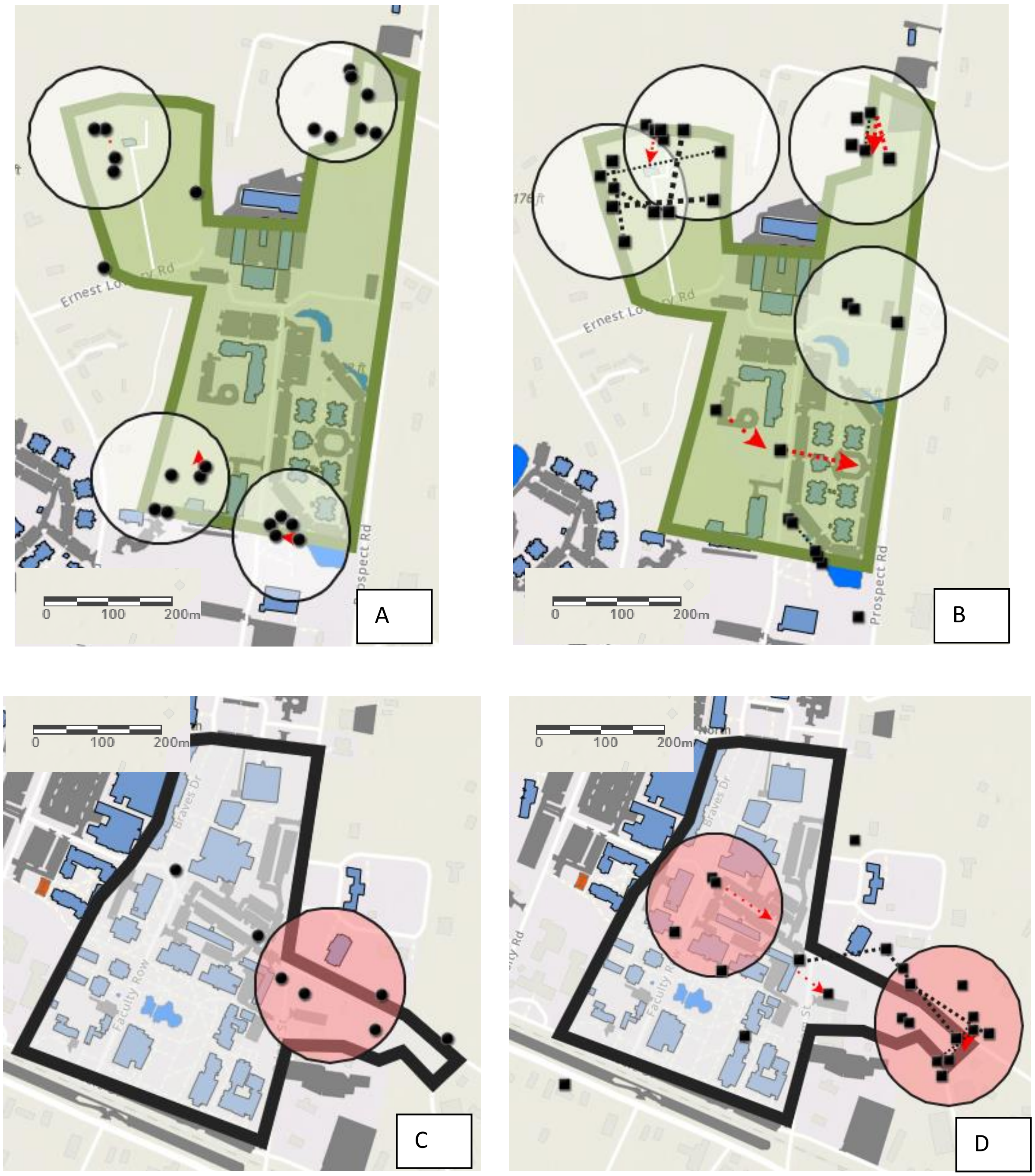
Species Richness and Species Evenness of Birds

The average avian species richness for the north site was 37.17 species per month and for the south site it was 25.33 species per month (Table 2). The Shannon Index for the fall semester north site was H = 2.55, and for the south site was H = 2.28. For the spring semester the Shannon index for the north site was H = 3.25, and for the south site it was H = 2.94.

Regression analysis

Our overall regression model showed that total species richness as the can be predicted by woodpecker species richness and date. The overall model $R^2 = 0.53$ and the overall regression model was significant (F (3,34) = 12.74, p<.05). We found that date (t = 4.90, p= 2.59E-05) and Woodpecker richness (t = 3.65, p = 0.000875) were each good predictors of species richness (species observed). Percentage of tree cover (site) was not a significant predictor in this model.

Figures and Tables:



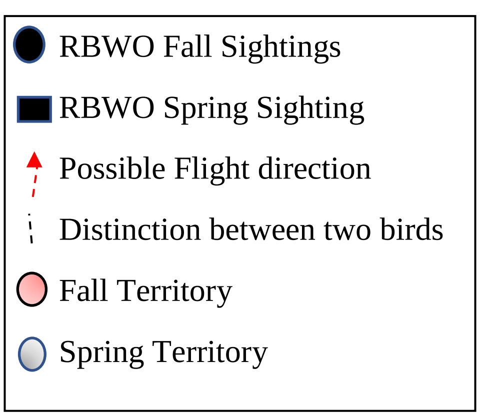


Figure 3. *M. carolinus* **(**Red-bellied woodpecker) territory sites and distribution, territory maps figures 3A and 3C fall field surveys. Territory map figures 3B and 3C are spring field season surveys.

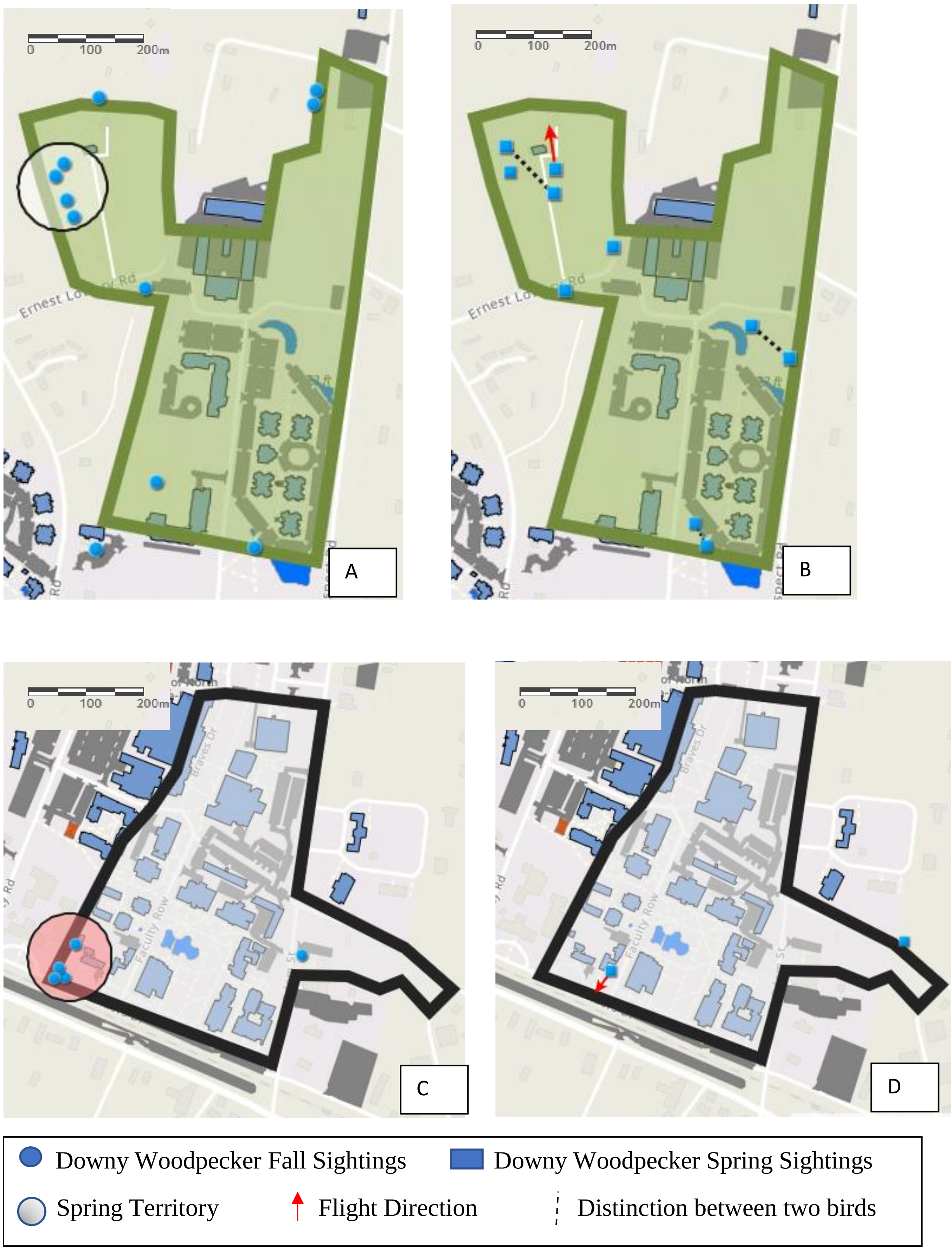


Figure 4. *Dryobates pubescens* (Downy Woodpecker) territory sites and distribution, territory map figures 4A and 4C are fall field surveys and map figures 3B and 3D the right are spring field surveys.

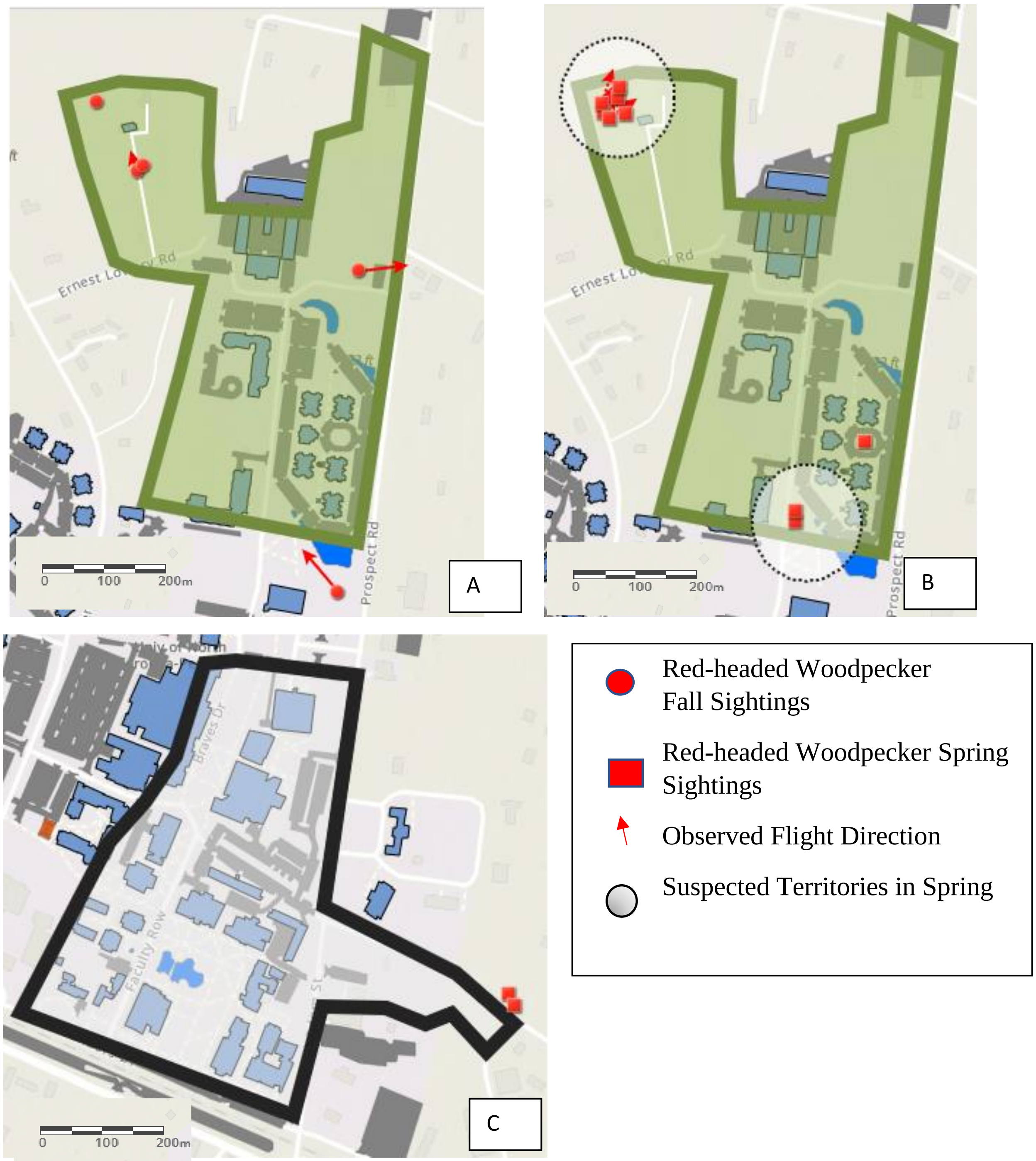


Figure 5. *M. erythrocephalus* (Red-headed Woodpecker) distribution and suspected territory sites. Figure 5A is the north site fall field survey, and the top right figure 5B is the north site spring field survey. The bottom figure 5C is the south site spring semester survey, no RHWO were observed in the south site during the fall semester.

Figure 6. *C. auratus* (Northern Flicker) territory sites and distribution, territory map figures 6A and 6C are fall field surveys and map figures 6B and 6D are spring field surveys

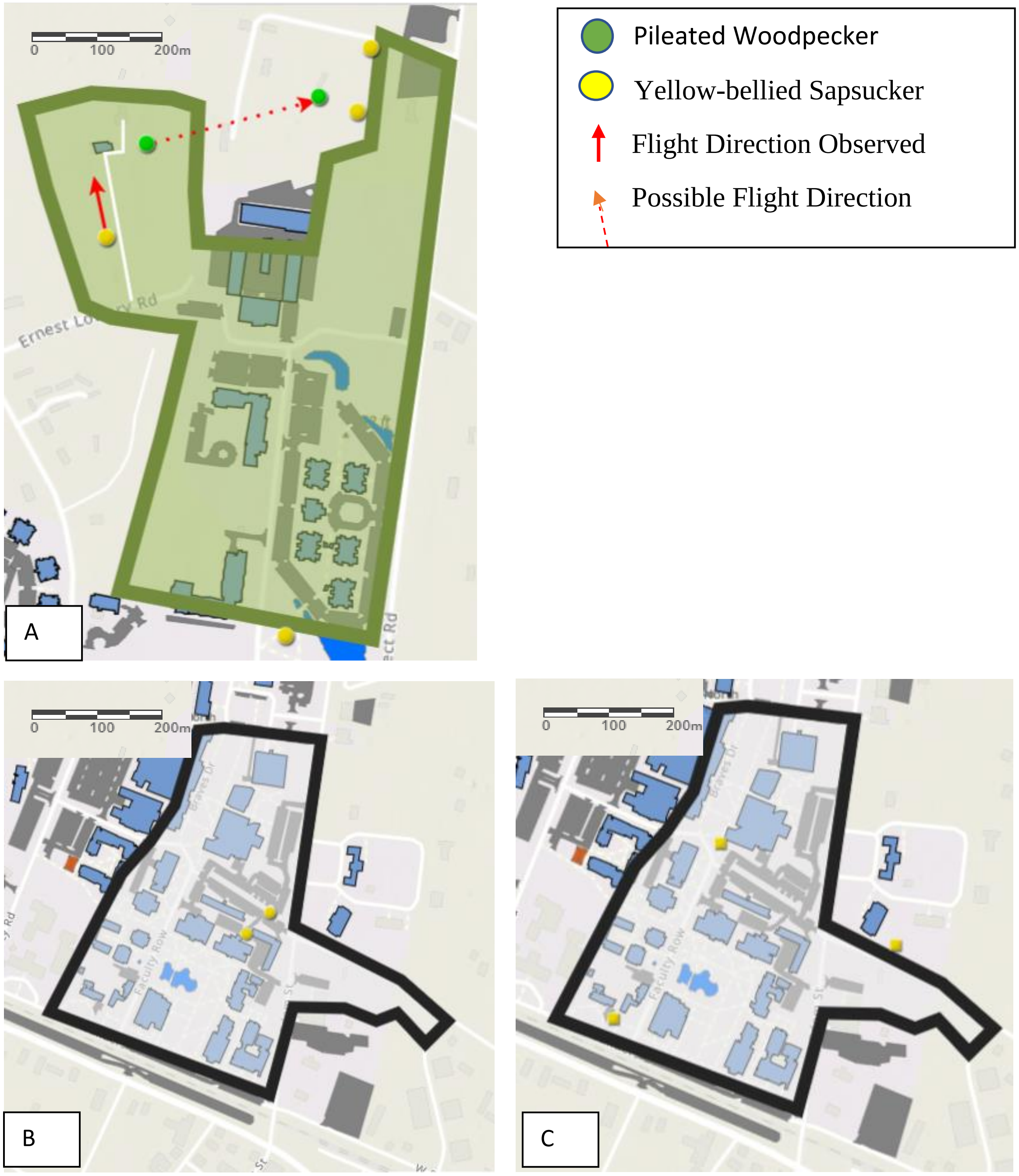


Figure 7. *D. pileatus* (Pileated Woodpecker) and *S. varius* (Yellow-bellied Sapsucker) sightings. The green dots are Pileated Woodpeckers. Territory map figures 7A and 7B are fall field surveys and map figure 7C is the spring field survey.

Table 1. Total basal area of each tree species within each plot

	Tree Basal Area per species in m												
Plot	Loblolly	Long Leaf	Water Oak	Laurel Oak	Willow Oak	Sweetgum	Nyssa	Red Maple	Japanese Maple	Black Cherry	Dogwood	River Birch	Chinese Chestnut
NW1	0	0	0.44	0.06	0	0.98	1.02	0.20	0	0	0	0	0
NW2	3.85	0	0	0	0.07	0.52	0.04	0.42	0	0	0	0	0
NM1	8.53	0	1.53	0	0	0	0	0	0	0	0	0	0.42
NM2	9.87	0	1.40	0	0	0	0	0	0	0	0	0	0
SW1	4.09	0	0.22	0.10	0	0.15	0	0	0	0.40	0	0	0
SW2	3.86	0	0	0.09	0	2.45	0	0	0	0.26	0.05	0	0
SM1	9.41	2.02	0	0	0	0	0	0	0.25	0	0	0	0
SM2	0	1.71	0	0	5.57	0	0	0	0	0	0	3.29	0

Table 2. Monthly species richness

Month	North Site	South Site
August 2020	27	*
September 2020	29	12
October 2020	40	37
February 2021	37	28
March 2021	41	37
April 2021	49	38
Avg. Total	37.17	25.33

*We did not collect data until September.

Discussion

Our data strongly suggest that woodpeckers are good bioindicators of avian biodiversity on the UNCP campus this is in agreement with the Virrkala (2006) review on woodpeckers as bioindicators. Our regression analysis revealed that the woodpecker species richness within a habitat can indicate if the habitat can support a diverse avian community. As expected, date was also a good predicter of overall species richness due to the migration timing of other bird species. Both sites were able to support woodpecker species, but woodpecker territories were more prevalent in the north site (17ha/64% forest coverage) than the south site (17ha /8.9% forest coverage). The Shannon indexes also showed that the northern site had greater avian biodiversity than the southern site. In our study the total area of forest cover was not a significant predictor of total avian species richness, but it is still important habitat factor for woodpeckers (Ilsoe et al. 2017).

Further research needs to be conducted on understanding the cavity nest web on the UNCP campus (Kilgo and Vukovitch 2014). Understanding how woodpeckers interact with other cavity nesting species will allow us to see how competitive and abundant other cavity nesting species are compared to the woodpecker population. Competition with other cavity nesting birds, like the European Starling, for nest cavities can negatively impact the population of woodpeckers (Vierling 1998). Intraspecies competition can also influence how woodpeckers will build their cavities (Vierling 1998), observing how woodpeckers are competing and where on campus they have territories will help us corelate how effective UNCP campus is at supporting the woodpecker population.

The basal area ANOVA showed that the composition of tree species across the campus are not differentiated enough to make a significant difference between the two sites. This means that tree species woodpeckers prefer are available in both sites. One major difference between the two sites was the percent coverage of forest; north 64.7%, south 8.9%. With 2 sites so close together this was not a significant factor for predicting avian species richness. Understanding how woodpeckers are utilizing the forest patches on campus and any boundary effects between patches may reveal why forest coverage was not a predictor of avian diversity on campus. The boundary effect is the changes in the population or community structure that happens at the boundary of two or more habitats (Matthysen 2002). Further research on how woodpeckers are using the fragmented tree coverage on campus needs to be done to understand this issue.

Mikusinski et al. (2001) had a similar study at a much larger scale as they were able to study 2317 plots that were 10x10km in size. Their study covered large areas of Poland and they were able to identify 70 species of birds, and 10 species of woodpeckers (Mikusinski et al. 2001). The R^2 of from Mikusinski et al. (2001) study and my study were both around 0.53, and Mikusinski et al's (2001) $p < 0.0001$ for woodpeckers also showed they were a good indicator for bird species richness. Our research shows that woodpeckers can be used to indicate biodiversity of birds. It is interesting that Mikusinski et al. (2001) research did not include the tree availability in his study, and it would be interesting to see how tree coverage and snag density in each plot affected woodpecker species richness and if it would be a significant predictor of total species richness.

My research can be replicated on other college campuses. I recommend that a year-round replication on college campuses such as those in the UNC system will allow study of how woodpeckers utilize different types of landscapes. If we can incorporate multiple campuses, we would have multiple plots that cover different landscapes like in Drever et al. (2010) and Mikusinski et al. studies (2001). Data from an expansion of our project would also help us understand how woodpeckers are utilizing anthropogenic environments and which environments they are responding to the best. Year-round data collection that generates yearly trends without temporal gaps would provide the most accurate picture of avian community structure and health.

UNCP has the potential to become a conservation site for woodpeckers. The campus supports a diverse community of birds and woodpeckers. As UNCP continues to grow and build new infrastructures it is important for construction managers to be conscious of the number of trees they cut down and how close buildings are to forested areas. I would recommend that UNCP invest more into creating green space that provides plenty of tree coverage, native tree species, and snags so woodpeckers and other bird species can benefit from those resources (Fröhlich and Ciach 2020). The addition of green spaces can lead to more research on how woodpeckers are utilizing green spaces that are on universities campuses and what type of environment woodpeckers prefer. Continued research should be done on woodpeckers on urbanized areas so people and woodpeckers can learn how to coexist.

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